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METHOD FOR PRODUCING GLASS OPTICAL PARTS

[Garasukogaku buhin no seizohoho]

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Claims /1*

1. A method for producing a glass optical part, characterized in that in a method of producing an optical part having a surface corresponding to the molding surface of the mold member by press molding glass in a soft state using a pair of mold members for molding, a temperature difference of 10°C or more is sustained in the aforementioned pair of mold members during glass hardening in the glass cooling process by the mold members after pressing to obtain an optical part having a highly accurate surface corresponding to the molding surface of the high-temperature-side mold member.

2. The method for producing an optical part described in claim 1, wherein the press starting temperature of the mold member which becomes the high-temperature side during glass

* [Numbers in the right margin indicate pagination of the original foreign text.]

hardening is in the range from the glass transition point to (strain point – 50°C) and it is at least 20°C higher than the press starting temperature of the mold member which becomes the low-temperature side during glass hardening.

3. A method for producing a glass optical part, characterized in that in a method of producing an optical part having a surface corresponding to the molding surface of the mold member by press molding glass in a soft state using a pair of mold members for molding, the thermal conductivities of the aforementioned pair of mold members are set differently, namely the thermal conductivity of one side mold member is set at least 5% higher than that of the other side mold member to obtain an optical part having a highly accurate surface corresponding to the molding surface of the low-thermal-conductivity-side mold member.

4. The method for producing a glass optical part described in Claim 3, wherein the pair of mold members are composed of the same base material, and a coating layer is formed on at least one mold member and the thickness of the coating layer and/or the base material is suitably set to make the thermal conductivities of the aforementioned pair of mold members different.

5. The method for producing an optical part described in any one of Claims 1-4, wherein the molding surface of the mold member which becomes the high-temperature side during glass hardening or low-thermal-conductivity-side mold member is nonspherical.

Detailed explanation of invention /2

Industrial application field

The present invention relates to a method for producing glass optical parts, more specifically it related to a method for obtaining optical parts having at least one surface of high accuracy in a pair of surfaces by press molding.

Prior art and problems to be solved by the invention

As methods for obtaining optical parts from glass materials by press molding, there are the so-called reheat press method and direct press method.

In the reheat press method, a glass blank closely resembling the final molded article is once formed, and the blank is put inside a mold device for molding, heated, and pressed to obtain a final molded article corresponding to the shape of the cavity being formed by mold members of the mold device.

In the aforementioned direct press method, molten glass is introduced into a mold device for molding and pressed to directly obtain a final molded article corresponding to the shape of the cavity being formed by mold members of the mold device.

However, it is preferred that the glass blank to be used in the aforementioned reheat method have satisfactory shape accuracy and surface accuracy and glass materials are cut and

polished to obtain glass blanks having the desired accuracy. However, cutting and polishing require much labor and thus sometimes the aforementioned direct method is utilized for production of the aforementioned glass blank.

As the direct press method, there is such a method of sandwiching molten glass flow from a nozzle between a pair of mold members facing each other in the horizontal direction, cooling and hardening the glass in the cavity thus formed to obtain a molded article having a prescribed form as described in, for example, Japanese Kokai Patent Application Nos. Sho 63[1988]-248727 and Hei 1[1989]-133948. In this method, a ring-form cutting member is arranged at the periphery of the optical surface-molding surface of one side mold member and pushed ahead simultaneously or after advancing of the mold member to cut and remove the protruded glass to form an optical part having a desired shape. According to this method, optical parts are obtained without leaving cutting marks of molten glass on the optical surface and thus it is preferred.

In the production of optical parts such as lenses or reflection mirrors having nonspherical optical surfaces especially by conventional cutting and polishing methods, a notably long production time was required, but if the aforementioned press molding is applied, the production time can be shortened.

In the aforementioned press molding, however, there was such difficulty that sometimes a defect was formed on the glass surface in the cooling process after the start of pressing, and this defect sometimes appeared on the first surface or the second surface so that it caused scattering of the optical property of optical parts to make the quality unstable.

Further, in the aforementioned reheat method, it sometimes slowly cooled below the strain point in molds even after glass hardening in order to prevent the generation of defect, but this requires a long time and there is a limit for cost reduction.

Thus, the present invention noticed that there are such optical parts which require high accuracy at only one side or optical parts which have a nonspherical surface at one side and an easily processible plane or spherical surface at the other side, and intended to provide a method for producing such glass optical parts always with high accuracy at one side and stable quality by concentrating the generation of defect during the aforementioned cooling process to the other side in order to obtain optical parts quickly and at low cost by press molding.

Means to solve the problems

To accomplish the aforementioned purpose, the present invention provides a method for producing a glass optical part, characterized in that in a method of producing an optical part having a surface corresponding to the molding surface of the mold member by press molding glass in a soft state using a pair of mold members for molding, a temperature difference of 10°C

or more is sustained in the aforementioned pair of mold members during glass hardening in the glass cooling process by the mold members after pressing to obtain an optical part having a highly accurate surface corresponding to the molding surface of the high-temperature-side mold member. /3

In the present invention, there is such a mode that the press starting temperature of the mold member, which becomes the high-temperature side during glass hardening, is in the range from the glass transition point to (strain point – 50°C) and it is at least 20°C higher than the press starting temperature of the mold member which becomes the low-temperature side during glass hardening.

Further, to accomplish the aforementioned purpose, the present invention also provides a method for producing a glass optical part, characterized in that in a method of producing an optical part having a surface corresponding to the molding surface of the mold member by press molding glass in a soft state using a pair of mold members for molding, the thermal conductivities of the aforementioned pair of mold members are set differently, namely the thermal conductivity of one side mold member is set at least 5% higher than that of the other side mold member to obtain an optical part having a highly accurate surface corresponding to the molding surface of the low-thermal-conductivity-side mold member.

In the present invention, there is such a mode that the pair of mold members are composed of a same base material, and a coating layer is formed on at least one mold member and the thickness of the coating layer and/or the base material is suitably set to make the thermal conductivities of the aforementioned pair of mold members different.

Further, in the present invention, there is such a mode that the molding surface of the mold member which becomes the high-temperature side during glass hardening or low-therma-conductivity-side mold member is nonspherical.

Application example

Next, an application example of the present invention will be explained by referring to the drawings.

Figure 1 is a cross-sectional view which shows the schematic process of the first application example of the method for producing glass optical parts by the present invention. In this application example, the direct press method was applied.

In the drawing, 2 is a molten glass flow nozzle connected to a glass melting device which is not shown, and 4 is molten glass continuously flowing down from the nozzle. 6 is a shear (cutting knife) for cutting molten glass flow 4 directly below the nozzle 2 at a suitable timing.

12, 12 are a pair of mold members arranged at both sides of the flowing-down molten glass, and in this application example, they are mold members for the molding of a convex

meniscus lens. 12a, 12a represent the molding surface for the formation of an optical surface, and the molding surface is finished to a mirror surface. These mold members are rotationally symmetrical, and arranged at the same axis by facing the molding surfaces to each other. A pair of mold sets is composed by including the mold members 12, 12'.

As the mold members 12, 12', the molding surface of moldings from Ni-base heat-resistant alloy material is polished to a surface roughness Rmax 0.01 μm, namely, the desired shape accuracy, coated with a nitride ceramic layer having a thickness of about 0.8 μm and utilized. Besides, Mo-base heat-resistant alloy, Fe-base heat-resistant alloy, stainless steel type heat-resistant alloy, Mo, TA, carbon and carbon composite, etc., can be used as the mold material. The coating layer is used for improving the hot strength of the base material, and carbides such TiC, SiC and TaC, etc., and C (diamond) beside nitrides such as BN, TiN, and AlN can be used. The coating layer can be formed by various film-forming technologies. The coating layer is not necessarily a single layer, and an intermediate layer for enhancing adhesion strength or heat resistance can be formed. Further, in the case of a coating layer formed by CVD process, ultra-precision grinding or polishing can be carried out in order to make the surface of the coating layer itself satisfactory. Further, in the case when base materials have high hot strength and can maintain shape accuracy even in press molding for sufficient numbers, soft materials such as platinum, platinum alloys, Ni and its alloy can be used as the coating layer.

In the mold set at the left side, the mold member 12 is fixed to a support 14, and the support 14 is attached to a fitting member 16. Further, a groove-forming ring 18 is attached to the periphery of the mold member 12. The tip of the ring has a blade shape. The ring 18 is fixed /4
to the aforementioned fitting member 16 by bolt using a spacer ring 20. The protruded amount of the blade of the ring 18 from the mold member molding surface 12a is set according to the thickness of the spacer ring. Furthermore, there are such cases where the blade does not protruded from the mold member molding surface 12a (protrusion amount 0) and the aforementioned groove-forming ring is not attached.

Furthermore, the mold members 12 have heater 22 and thermocouple 24 at the inner part.

Then, the fitting member 16 is supported on a stand capable of reciprocally moving along the A-B direction, which is not shown in the drawing. The reciprocal moving is carried out by a driving means which is not shown in the drawing.

So far the mold set at the left side has been explained, but the mold set at the right side is practically the same except the shape of the mold member molding surface 12a', and "'" is attached to the corresponding member. In the mold set at the right side, the most advanced stopping position in the B direction is set by a stopper which is not shown in the drawing. The position of the stopper is variable and the aforementioned stopping position is set by adjusting the stopper position.

Next, the production process will be explained according to the drawing.

First, as shown in Figure 1(a), the mold sets at the left and right sides are opened at a prescribed interval, and molten glass 4 is allowed to flow down from the nozzle 2 between the mold members 12, 12' under maintaining of the shears 6 in an open state. Then, the time when the bottom end of the molten glass reaches the position lower than the mold members or the glass bottom end including the shear mark reaches the position lower than the bottom end of both groove-forming rings 18, 18' at the moment when the mold member molding surface 12a, 12a' of both mold sets at the left and right sides contacts with the glass 4 in the next process is detected by a sensor, which is not shown in the drawing, as shown in Figure 1(a).

Next, the right-side mold set advances along the B direction until it contacts with the stopper based on the detection signal. The left-side mold set advances along the A direction by an extremely slight delay with respect to the advance motion of the right-side mold set. By this action, as shown in Figure 1(b), the molten glass is pressed corresponding to the cavity formed by a pair of mold members 12, 12' and groove-forming rings 18, 18'. Furthermore, at this time, as shown in Figure 1(b), the tips of the groove-forming rings 18, 18' are set apart by an interval D without contacting each other; thus, grooves are formed on both the left and right surfaces corresponding to the mold member molding surfaces 12a, 12a' of the pressed molten glass. A glass optical part base body 30 is formed at the inner side of the grooves.

Next, as shown in Figure 1(c), the shears 6 are closed to cut the molten glass 4. By this action, a lug section 32 protruding to the outside of the groove is formed at the periphery of the aforementioned glass optical part base body 30.

Then, the left and right mold sets are shifted downward about several cm to 10 cm, with respect to the nozzle 2 and shears 6, by a driving means, which is not shown in the drawing, under retention of the pressed state, and at the same time the shears 6 are opened to divide the glass flow.

The pressed state is continuously maintained until the glass is cooled by the mold members 12, 12' and hardened. In this time, the left-side mold set continuously applies the pressing pressure to the glass without being stopped by stopper, etc.

Then, as shown in Figure 1(d), the left and right mold sets are opened and the molded product is taken out. A removal robot, which is not shown in the drawing, is utilized for removing.

Figure 2 is a front view of a molded article obtained by the above processes.

In the drawing, 30 is the optical part base body; 32 is a lug section protruding to outside; 34 is a groove formed on both surfaces between the base body 30 and the lug section 32.

Furthermore, in the aforementioned process, the mold members 12, 12' are PID-controlled to a fixed temperature based on temperature measurement results by

thermocouples 24, 24'. The fixed temperature can be suitably changed. Particularly, in this application example, it is controlled in such a manner to maintain the temperature difference between the mold member 12 and the mold member 12' at 10°C or higher during glass hardening. By this temperature control, the generation of effects during cooling is sufficiently suppressed at the surface of the optical part being contacted with the high-temperature-side mold member as compared with the surface of the optical part being contacted with the low-temperature side, and thus the surface accuracy of the high-temperature side is always satisfactory.

Such control can be realized by setting the press starting temperature of one side mold member 12 at least 20°C higher than the press starting temperature of the other side mold member 12' in the temperature range from the glass transition temperature to (strain point – 50°C).

Further, the thermal conductivity of one side mold member is controlled to at least 5% higher than the thermal conductivity of the other side mold member so that a glass optical part having high surface accuracy corresponding to the molding surface of the low-thermal-conductivity-side mold member can be obtained. In this case, for example, both mold members 12,12' are formed from the same base material, and a coating layer is formed on the molding surface of at least one mold member; further, the coating layer thickness and/or material quality is suitably set in both mold members to make the thermal conductivities of the aforementioned pair of mold members different.

The thickness of the molded product is decided by the viscosity of the molten glass, temperature and pressing pressure of mold members, and other molding conditions, and they are suitably controlled to obtain a molded product having a desired thickness. The viscosity of the molten glass can be controlled in a range of, for example, 10^5 -10^2 poise. The pressing pressure can be controlled in a range of, for example, 1-500 kg/cm^2.

The molded product thus obtained can be used by setting in a mirror cylinder as it is or after removing the lug section 32.

The removal can be mechanically and easily carried out by generating tensile stress at a desired position due to that grooves 34 have been formed. Namely, for example, it can be removed by applying force with the fingers to divide it, or it can be removed by a falling impact from a small height. Furthermore, it can be removed by supporting the base body 30 using an exclusive jig and applying force to the lug section 32.

Further, the optical part thus obtained can be utilized as a surface reflection mirror by forming a reflective film on the high-accuracy side surface or as lens having satisfactory surface accuracy at both surfaces by grinding and polishing the surface opposite to the

high-temperature-side surface to make it flat or spherical if necessary. It is especially effective in the case where the high-temperature-side surface in pressing is nonspherical.

Figure 3 is a cross-sectional view showing the schematic process of a second application example of a method for producing glass optical parts by the present invention. The reheat press method was applied in this application example.

In the drawing, 42 is a floorboard; 44 is a ceiling plate; 46 are posts connecting them. Four posts are arranged in parallel along the top and bottom direction.

48 is a top side base member, and the base member is fixed to the aforementioned posts 46 at a desired position by bolts 50. An upper mold member holder 52 is fixed at the bottom surface of the base member 48 and the upper mold member 54 is held by the holder. 54a is the molding surface formed at the bottom surface of the upper mold member. A spacer 56 is placed between the upper mold member 54 and the base member 48. A heater 58 and a thermocouple 60 are arranged inside the upper mold member 54.

62 is a lower side base member, and the base member is attached to the posts 46 in a state capable of moving along the top and bottom directions. A support 64 for barrel-shaped component is fixed on the upper surface of the base member, further a barrel-shaped component 66 is fixed on the support. The barrel-shaped component is provided with heater 68 and thermocouple 70. In the inner part of the barrel-shaped component 68[sic; 66], lower mold member 72 is arranged at such a state of freely sliding along the up-and-down direction. 72a is the molding surface formed on the upper surface of the lower mold member. Heater 74 and thermocouple 76 are arranged inside the lower mold member 72.

The upper mold member 54, barrel-shaped component 66 and (p.134) lower mold 6
member 72 are axially arranged, and the upper mold member 54 can be moved along the up-and-down direction by sliding on the barrel-shaped component 66.

On the other hand, cylinder holding member 78 is attached to the bottom side of the lower side base member 62, and first cylinder 80 is fixed on the holding member. The piston rod of the cylinder faces the upper direction, and its tip collides with the bottom end of extrusion rod 82. The rod penetrates the bottom side base member 62 along the up-and-down direction, and its upper tip collides with the bottom end of the lower mold member 72. And the rod 82 freely slides along the up-and-down direction with respect to the bottom side base member 62. Further, second cylinder 84 is fixed on the floorboard 42, and the upper end of the piston rod of the cylinder collides with the bottom surface of the cylinder holding member 78.

Furthermore, sealing between the part which includes the sliding section, which is positioned at the upper side of X-X', and the part which is positioned at the bottom side of X-X', was carried out using O rings.

In the device explained above, the part positioned at the upper side of X-X' is evacuated to make a vacuum and filled with nitrogen gas, and a glass blank is heated to a viscosity of about $10^{[illegible]}$ poise in a furnace, which is not shown in the drawing, and fed onto the lower mold part 72 by a shooter, which is not shown in the drawing.

Then, the bottom side base member 62 is raised by operating the second cylinder 84 so that the barrel-shaped component 66 is fit to the bottom of the upper mold member 54, and the mold is closed, followed by pressing. The press state by the upper mold member 54, barrel-shaped component 66 and lower mold member 72 is maintained until the glass is cooled and hardened. During this cooling, the upper mold member 54 and the lower mold member 72 are temperature-controlled based on the temperature measurement results of thermocouples 60, 76 in the same manner as in first application example.

Finally, the bottom side base member 62 is lowered by operating second cylinder 84 to release the fitting of the barrel-shaped component 66 and the upper mold member 54 to open the mold. Then, the first cylinder 80 is operated to raise the lower mold member 72 with respect to the barrel-shaped component 66 by the extrusion rod 82 so that the molded product is removal. A taking out robot, which is not shown in the drawing, is utilized for taking out the molded product.

In a conventional reheat press, glass is retained in the mold even after glass hardening and slowly cooled to the strain point or lower so as to prevent the formation of a temperature difference between both surfaces as much as possible. However, in the present invention, the surface accuracy at the desired one surface can be satisfactorily maintained even when taken out immediately after glass hardening, and thus the press time can be greatly reduced.

Figure 4 shows a modification example of the second application example.

In this modification example, the barrel-shaped component 66 in the device of Figure 3 is not used, but groove-forming rings 86, 88, same as in the first application example, are installed at the periphery of the upper mold member 54 and the lower mold member 72, respectively.

Furthermore, even in this application example, temperature control in the mold members is carried out as in the first and second application examples.

The results on glass optical parts produced by using the above methods are shown below.

<u>Application Example 1</u>

A double-spherical convex lens with outer diameter of 21.0 mm, maximum ray effective aperture 20.0 mmϕ, thickness of 1.55 mm, and thickness difference of 0.81 mm was manufactured using a device shown in Figure 1 as follows.

Double flint glass having a transition point of 430°C and strain point of 373°C was stabilized at a viscosity of 10^4 poise and flowed down from a platinum nozzle with an inner diameter of 15 mm.

The mold members 12, 12' had a diameter of 21.0 mm and the protruded amount of the tip of groove-forming rings 18, 18' was set at 0.5 mm. The mold members were manufactured by shaping a Ni-base heat-resistant alloy (Inconel 718) as a base material and forming a 0.8-μm-thick AlN ceramic layer on the molding surface.

As the press and cooling conditions, the mold member temperature (T_1) at the press /7
start is shown in Table 1, and the pressing pressure and pressing time were set at 20 kg/cm^2 and 18 sec, respectively. In experiment Nos. 1-4, the mold member temperature was controlled to a constant temperature until the glass hardened (mold-release time), but in experiment Nos. 5-8, mold heating was stopped directly after pressing started, and the mold member temperature (T_2) at mold releases is shown in Table 1.

Under each condition, 100 units of optical parts were manufactured. The surface accuracy at both surfaces of the lenses thus obtained was measured, and those having within 3 Newton rings total of astigmatism, smoothness and spherical surface accuracy on each surface were judged as good products. The results are shown in Table 1.

Table 1

Experiment No.	T_1 (°C) Mold member 12/ Mold member 12'	T_2 (°C) Mold member 12/ Mold member 12'	*Good product ratio (%)* *Left-side convex surface/* *Right-side concave surface*
1	*410/410*	*410/410*	*41/54*
2	*430/400*	*430/400*	*100/0*
3	*400/420*	*400/420*	*0/100*
4	*370/410*	*370/410*	*0/100*
5	*430/430*	*404/398*	*64/84*
6	*440/410*	*412/394*	*100/37*
7	*380/420*	*359/388*	*49/100*
8	*400/400*	*377/370*	*22/16*

The conditions in experiment Nos. 1, 5 and 8 are beyond the range of the present invention and they are comparative examples.

It is understood from the above results that when the temperature difference between both mold members 12,12' at glass hardening (mold release) is 10°C or higher, the accuracy of the high-temperature-side surface is surely and satisfactorily retained. Namely, effects during cooling concentrate in the low-temperature-side surface. In the comparative examples, these effects are distributed in both surfaces and the good product ratio in both surfaces is insufficient.

Application Example 2

The same optical parts were manufactured using the same device as in Application Example 1. However, groove-forming rings were not used.

In this application example, the temperature of both mold members 12, 12' was controlled to a constant temperature of 380°C until glass hardening (mold release) from the press starting. The pressing pressure was 20 kg/cm^2 and the pressing time was 15 sec.

The base material, material for coating layer and the thickness used for mold members 12, 12' are shown in Table 2. As the base material for the mold members, Inconel 718 ("Inconel"), two types of MoB-system cermets with different additives ("MoB(1)," "MoB(2))," TiN-system cermet ("TiN") or WC-system superhard alloy ("WC") was used. Further, AlN, TiN and Ti were used for the coating layer.

In each experiment, the thermal conductivity of both mold members and the difference in thermal conductivity between both mold members Δ [(thermal conductivity of mold member having high thermal conductivity – thermal conductivity of mold member having low thermal conductivity)/(thermal conductivity of mold member having low thermal conductivity)] are shown. The thermal conductivity (unit: cal/cm·sec·°C) was determined by the laser flash method (100°C) using a 3-mm-thick flat plate sample prepared at the same time when the mold members were manufactured.

In each experiment, 100 units of optical parts were obtained. The surface accuracy at both surfaces of the lenses thus obtained was measured, and those having within 3 Newton rings total of astigmatism, smoothness and spherical surface accuracy on each surface were judged as good products. The results are shown in Table 2.

Table 2

Experiment No.	Material for mold member/ Thermal conductivity		Δ	Good product ratio (%)
	Mold member 12	Mold member 12'	%	Left side convex surface/ Right side concave surface
1	Inconel/0.057	Inconel/0.057	0	31/62
2	Inconel/0.057	Inconel + AlN 2 μm/0.061	7	100/0
3	Inconel/0.057	MoB(1)/0.032	78	0/100
4	MoB(1)+AlN 3 μm/0.036	MoB(1)+TiN 1 μm/0.034	6	51/100
5	MoB(1)/0.032	MoB(2)/0.031	3	48/70
6	MoB(2)0.031	TiN/0.050	61	100/33
7	WC+Ti 10 μm +TiN 1μm/0.19	WC+TiN 1 μm /0.20	5	100/49

The conditions in experiment Nos. 1 and 5 are beyond the range of the present invention, and are comparative examples.

It is understood from the results that the surface accuracy of the surface at the low-thermal-conductivity mold member 12,12' side is surely and satisfactorily retained in the case of the thermal conductivity difference Δ of 5% or higher. Namely, it is due to that in the mold member at the high-thermal-conductivity side, heat conduction from high-temperature glass is large during cooling in the mold member and the cooling rate of the glass becomes high so that the surface becomes the low-temperature side and effects concentrate in this surface. In the comparative examples, these effects are distributed in both surfaces and the good product ratio in both surfaces is insufficient.

Application Example 3

A lens of nonspherical convex surface and spherical concave surface with outer diameter of 25.6 mm, maximum ray effective aperture 23.4 mmϕ, thickness of 1.02 mm, and thickness difference of 1.29 mm was manufactured using a device shown in Figure 3 as follows.

Spherical glass with diameter of 12.4 mm from double-crown glass having a transition point of 659°C and strain point of 602°C was preheated in a furnace up to a viscosity of 10[illegible] poise and introduced into the mold.

As the press and cooling conditions, the temperature of barrel-shaped component 66 was set at 560°C, and temperature control [range] of the upper mold member 54 and lower mold member 72 and material quality for the both upper and lower mold members are shown in Table 3 (press starting temperature - glass hardening (mold release) temperature is shown). Further, the pressing pressure and the pressing time were set at 20 kg/cm^2 and 20 sec, respectively, and after pressing, the mold was opened to carry out mold release.

For the mold members 54, 72, the base material, coating layer and its thickness shown in Table 3 were employed. As the mold members, two types of WC-Co-system superhard alloys with different binders were coated with a TiN layer at a thickness of 1 μm ("WC(1), WC-(2)") and used or two types of normal-pressure-sintered SiC having different compositions ("SiC(1)", "SiC(2)") were coated with SiC ("CVDSiC") by the CVD process and used.

In each experiment, 100 units of optical parts were obtained. The surface accuracy at both surfaces of lenses thus obtained was measured, and those having Newtons rings not exceeding 3 total of astigmatism, smoothness and spherical surface accuracy in the case of the spherical surface are judged as good products while those having Newtons rings not exceeding 1 total of astigmatism, smoothness and spherical surface accuracy in the case of the nonspherical surface are judged as good products. The results are shown in Table 3.

Table 3

Experiment No.	Material for mold member/thermal conductivity/temperature condition		Good product ratio (%)
	Mold member 54	Mold member 72	Upper-side concave surface /Lower-side convex surface
1	WC(1)/0.20/ 580 → 580	WC(2)/0.16/ 580 → 580	65/100
2	WC(2)/0.16/ 570→570	WC(2)/0.16/ 600→600	20/100
3	WC(1)/0.20/ 650→548	WC(2)/0.16/ 650→572	43/100
4	WC(2)/0.16/ 635→555	WC(2)/0.16/ 650→570	93/100
5	WC(2)/0.16/ 580-580	WC(2)/0.16/ 580-580	78/62
6	SiC(1)+CVD SiC 100 μm/0.23/ 600-600	SiC(2)+CVD SiC 100 μm/0.15/ 600-600	47/100
7	SiC(2)+CVD SiC 800μm/0.158 /600→600	SiC(2)+CVD SiC 100μm/0.15 /600→600	66/100

The condition in experiment No. 5 is beyond the range of the present invention, and it is a /9
comparative example.

It is understood from the results that the surface accuracy of the surface at the low-thermal-conductivity mold member side is surely and satisfactorily maintained in the case of experiment Nos. 1, 3, 6 and 7, wherein the thermal conductivity difference Δ between the mold members 54, 72 was 5% or higher. Further, it is also understood that the accuracy of the surface at the high-temperature side is surely and accurately maintained even in the case of experiment

Nos. 2, 3, and 4, wherein the temperature difference at glass hardening (mold release) between the mold members 54, 72 is 10°C or higher. In the comparative example, the effects are distributed in both surfaces and the good product ratio in both surfaces is insufficient.

Application Example 4

A concave meniscus lens with a nonspherical concave surface and a spherical convex surface with outer diameter of 21.0 mm, maximum ray effective aperture of 20.0 mmϕ, thickness of 3.80 mm, and thickness difference of 1.22 mm was manufactured using a device shown in Figure 3 but with a mold having a structure shown in Figure 4 as follows. Furthermore, the protruded amount of groove-forming rings 86, 88 was 0.3 mm.

A disk-form glass with diameter of 25 mm and thickness of 4 mm from double-crown glass having a [illegible] transition point of 659°C and strain point of 602°C was preheated in a furnace to a viscosity of 10^6 poise and put on the groove-forming ring 88 at the lower mold member side using a finger robot.

The press and cooling conditions, temperature control of the upper mold member 54 and lower mold member 72, and materials for the upper and lower mold members are shown in Table 4 (press starting temperature – glass hardening (mold release) temperature is shown). Further, the pressing pressure and pressing time were set at 20 kg/cm and 20 sec, respectively, and after pressing, the mold was opened to carry out mold release.

The base material quality, coating material quality and coating thickness for the mold members 54, 72 are shown in Table 4. Two types of WC-Co-system superhard alloys with different binders were coated with a TiN layer at a thickness of 1 μm and used ("WC(1)", "WC(2)") as the mold members.

In each experiment, 100 units of optical parts were obtained. The surface accuracy at both surfaces of lenses thus obtained was measured, and those having Newton rings not exceeding 3 total of astigmatism, smoothness and spherical surface accuracy in the case of the spherical surface are judged as good products while those having Newton rings not exceeding 1 total of astigmatism, smoothness and spherical surface accuracy in the case of the nonspherical surface are judged as good products. The results are shown in Table 4.

Table 4

Experiment No.	Material for mold member/thermal conductivity/temperature condition		Good product ratio (%)
	Mold member 54	Mold member 72	Upper-side concave surface /Lower-side convex surface
1	WC(2)/0.16/ 580 → 580	WC(1)/0.20/ 580 → 580	100/78
2	WC(2)/0.16/ 600→600	WC(2)/0.16/ 570→570	100/45
3	WC(2)/0.16/ 600→600	WC(2)/0.16/ 600→600	67/28

The condition in experiment No. 3 is beyond the range of the present invention, and it is a comparative example.

It is understood from the above results that the surface accuracy at the low-thermal-conductivity mold member is surely and satisfactorily retained in the case of experiment No. 1 wherein the thermal conductivity difference between both mold members 54, 72 was 5% or higher. Further, it is also understood that the surface accuracy at the high-temperature side is surely and accurately retained even in the case of experiment No. 2, wherein the temperature difference between both mold members 54, 72 is 10°C or higher. In the comparative example, effects are distributed in both surfaces and the good product ratio is insufficient for both surfaces.

Effect of invention

As explained above, according to the present invention, an optical part having a highly accurate surface corresponding to the molding surface of the high-temperature-side mold member can be obtained by sustaining a temperature difference of 10°C or higher in a pair of mold members during glass hardening in the glass cooling process by the mold members after pressing. Further, an optical part having a highly accurate surface corresponding to the molding surface of the low-thermal-conductivity-side mold member can be obtained by setting the thermal conductivities of a pair of mold members differently, namely setting the thermal conductivity of one side mold member at a thermal conductivity at least 5% higher than that of the other side mold member. This way, effect generation during cooling is concentrated in one

surface so that the other surface is always maintained at a high accuracy and an optical part having stable quality can be produced at a low cost. Particularly, its effect is large when it is /10 applied to optical parts wherein high accuracy is required only at one side and spherical optical parts which have a nonspherical surface at one side and an easily processible flat or spherical surface at the other side.

Brief description of the figures

Figure 1 is a cross-sectional view which shows the schematic process of the first application example of the method for producing glass optical parts by the present invention.

Figure 2 is a front view of a molded article.

Figure 3 is a cross-sectional view which shows the schematic process of a second application example of the method for producing glass optical parts by the present invention.

Figure 4 shows a modification example of the second application example.

2: Nozzle, 4: Molten glass
6: Shear
12, 12': Mold member for molding
12a, 12a': Molding surface
18, 18': Groove-forming ring
22, 22': Heater
24, 24': Thermocouple
30: Optical part base body
32: Lug, 34: Groove
54: Upper mold member, 66: Barrel-shaped component
72: Lower mold member
54a, 72a: Molding surface
58, 68, 74: Heater
60, 70, 76: Thermocouple
86, 88: Groove-forming ring

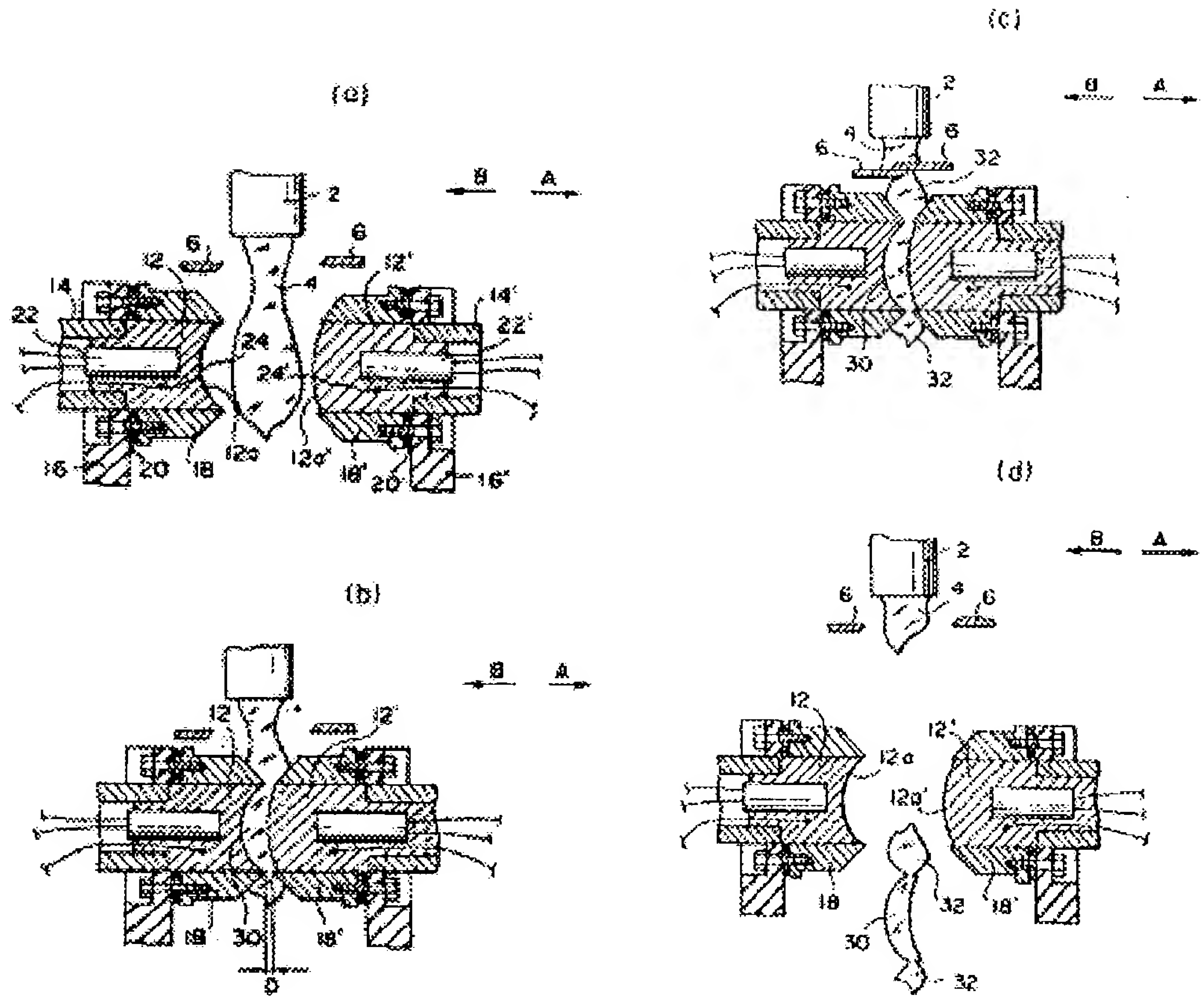

Figure 1

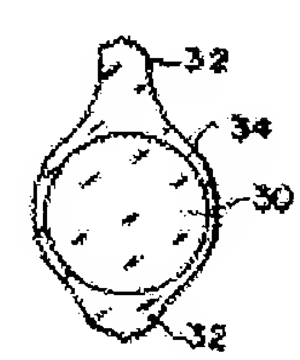

Figure 2

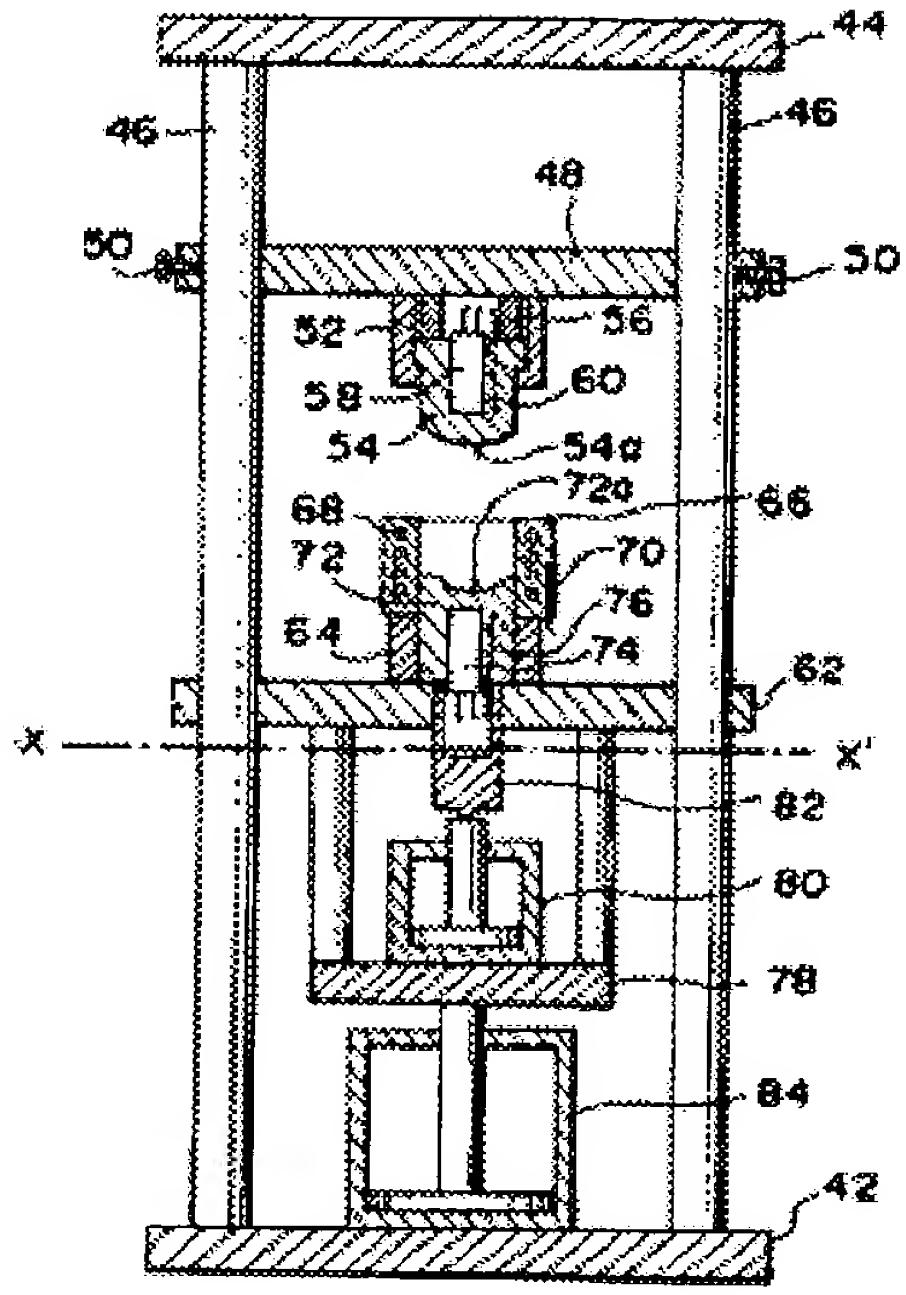

Figure 3

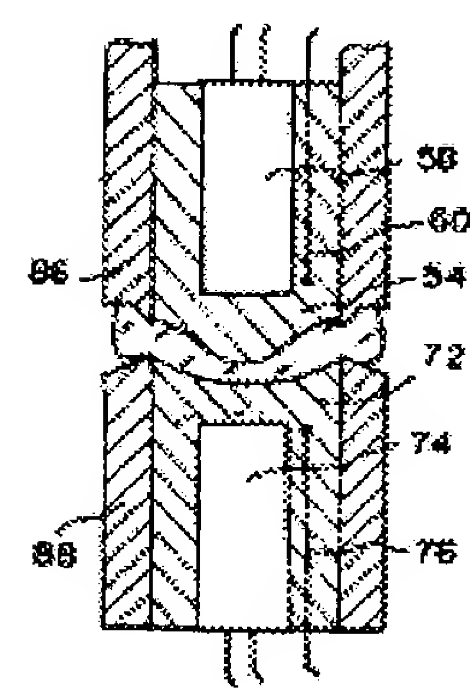

Figure 4